CONCRETE PAVEMENT

Contractor Concrete Mix Design

The provision requires the contractor to produce and submit a concrete mix report. Complete and use department worksheet WS5014 "Concrete Mix Design" as the cover page to the mix design. The contractor can choose to use the standard mixes from standard spec 501 or a contractor mix design. When the contractor chooses to use a standard mix design the contractor is still responsible for the performance of the mix. The concrete mix report shall be produced and submitted according to the QMP provision with the exception that for concrete pavement, slag and fly ash is not required, but may be used as a replacement for Portland cement according to QMP Concrete Pavement 415.3000.S.

Entrained Air Content Testing

Plot air content data on department worksheet WS5016 "Air Content Control Chart for Concrete Pavement".

Cylinder Fabrication, Curing, and Strength Testing

The contractor QC staff fabricates, cures, and tests cylinders to determine the 28-day compressive strength for each sublot. A set of three 6X12-inch QC cylinders is required. An additional set of three companion cylinders is required for sublots the engineer designates.

The contractor selects 2 of the three QC cylinders at random and breaks them. If the breaking strengths are close to the same, the average strength of those 2 cylinders defines the sublot strength. If the 2 breaking strengths are significantly different, the contractor breaks the third QC cylinder and determines the sublot strength as the average of the 2 highest strength cylinders.

The purpose of these 28-day strength cylinders is to demonstrate the quality of the concrete and the potential strength of the produced concrete. These cylinders are independent of the cylinders cast and broken by the contractor for opening to traffic. Cylinders for opening to traffic must be fabricated and cured according to standard spec 415.3.17.

The average strength and the variability of strength for the cylinders in the lot may result in a bonus or penalty to the contractor for the lot. Therefore, care should be taken for casting, curing, transporting, and breaking these cylinders. Better cylinder care will result in higher and more consistent strengths. When vibratory methods are used to consolidate the material in a cylinder mold, the technician must take care not to over vibrate the material. Over vibration could lead to segregation of the material and lower strengths.

Record cylinder fabrication data on department worksheet WS5018 "Compressive Strength Cylinder Fabrication Summary Table for Concrete Pavement". This worksheet may be copied and used for recording data.

The cylinders shall be cured for the first 24 to 48 hours after molding according to the provision. After the initial curing the cylinders shall be transported to a laboratory and cured for the remainder of 28 days according to the QMP provision.

At 28 days the cylinders are broken to failure on a compressive strength test machine. The test machine is required to automatically record the date, time, rate of loading, and maximum load of each cylinder. A printout of this data is required to accompany the compressive strength documentation for each cylinder that represents a sublot. Record test results, and make the calculations to determine the pay adjustment for the lot, on department worksheet WS4151 "Incentive Strength Concrete Pavement". The department will determine the pay adjustment for each lot based on the average strength and standard deviation of the strength cylinders for the lot. Lot strength averages and standard deviations will be calculated according to the following:

LOT MEAN:

$$X = \frac{C_1 + C_2 + C_3 + \cdots + C_n}{n}$$

Where: X = lot mean

C = sublot average strength for each sublot

n = number of sublots in lot

LOT STANDARD DEVIATION:

$$S_n = \sqrt{\frac{(C_1 - X)^2 + (C_2 - X)^2 + \cdots (C_n - X)^2}{n-1}}$$

Where: Sn = lot standard deviation

C = sublot average strength for each sublot

X = lot mean

n = number of sublots in lot

The compressive strength pay adjustment for a lot is based on the calculated average strength of the lot minus the standard deviation. This pay adjustment is detailed in the pay adjustment table of section G of the provision.

Section G of the provision states that the department will not pay a compressive strength bonus on material quantities determined to have out of specification air content or slump.

Companion Cylinders

The engineer must tell the contractor where to cast companion cylinders by designating a sublot. The contractor is initially responsible for those cylinders, but the engineer should take possession of them as soon as it is practical after the 24-hour initial curing but no later than 3 calendar days after they are cast. The engineer should initiate standard curing, in a temperature and humidity controlled curing room or tank, as soon as they take possession of the companion cylinders. The purpose of the companion cylinders is to check for excessive variability in strength of cylinders made from the same sample by the same person, cured under like conditions, but tested with different equipment. If standard procedures are not followed, the results have little or no value. If the department fails to designate a companion cylinder sublot, or subsequently mishandles cylinders, and the contractor has fulfilled their obligation under the contract, the contractor will not be held responsible for missing or questionable companion test results.

Temperature

Recording concrete temperature during the fabrication of strength cylinders will provide the contractor information that may be useful on future projects. High concrete temperatures result in fast hydration of the concrete, thus reducing the time before sawing must occur. If the hydration process is too fast, it can result in shrinkage cracking and/or low strength. Record temperature data on worksheet WS5018.

Corrective Action

Corrective Action shall be implemented according to the provision.

Department Testing

The department or a department representative will perform verification and independent assurance sampling and testing as described in the provision. Sampling and testing will be performed by an HTCP certified technician.

Verification Testing

Verification testing will be performed by a department representative on samples collected independently of the contractor's samples in accordance with the provision. Testing of the material will be conducted in a separate laboratory and with separate equipment from the contractor's tests.

Independent Assurance Review

Independent assurance reviews will be conducted by a department representative in accordance with the provision and the department's Independent Assurance Program. These reviews will be made of the contractor's quality control and the department's verification sampling and testing equipment and personnel.

Companion Cylinders

In addition to the verification and independent assurance testing described in the special provision, the department is responsible for curing and testing companion cylinders. The department will compare the average strength of a pair of companion cylinders to the contractor's QC test results from the same sublot. If those average strengths vary by more than about 10 percent, the source of that variability should be investigated.

The point of companion cylinders is to isolate the potential sources of variability to handling and testing procedures that take place after the initial field curing. First check that the department has provided continuous standard curing and has prepared and tested the companion cylinders according to the applicable AASHTO standards. If standard procedures are not adhered to, the comparison has little or no validity.

There are a number of potential sources of variability. Contact the region IA personnel to help determine what may have caused the difference between the companion and associated QC strengths. IA personnel should be able to isolate the problem and suggest an appropriate remedy.

Document all companion test results. Be sure to indicate which QC cylinders were used in the comparison and indicate the results of that comparison even if the difference is less than 10 percent. Include details regarding any investigation done, the conclusions of the investigator, and actions taken to remedy the problem. Include this documentation in the permanent project records. The best way to assure that the information is not lost is to include it electronically in an RFI 155 report entered into the materials tracking system.

Incentive Strength Concrete Pavement

The compressive strength incentive will be paid through bid item 415.2000.S. The price for this item is fixed for the contract bidding; thus, each contractor bids the same value for the item. The fixed cost for the item is estimated at 80% of the maximum incentive available for compressive strength on the project. This item provides for the engineer to pay for incentive, without the need of a construction change order. Because a contractor can earn 0% to 100% of the maximum strength incentive attainable for the project and the contract bid item was at 80% of the maximum attainable, a project can result in 0% to 125% pay for the incentive for compressive strength bid item. Compressive strength disincentives will be administered in the accounting system through the standard method of an eight hundred number, set up by the engineer. Incentives or disincentives for each lot are determined based on requirements in the special provision.

ANCILLARY CONCRETE

Concrete Mix Design

The contractor may elect to use a concrete mix from standard spec 501 or, where one of the grade A mixes is allowed under standard spec 501.3.1, an approved QMP mix design for concrete pavement or structural concrete from the current contract.

QC Documentation

Document all observations, inspection records, mix adjustments, cylinder identification, and test results daily to the engineer using department worksheet WS5013 "Ancillary Concrete Daily Test Report". Submit original testing records to the engineer in a neat and orderly manner within 10 days after completing concrete production.

Sampling Frequency

Randomly choose sample locations using the procedures described in Procedure 4-15-12. Use whichever combination of the following criteria resulting in the greatest number of tests.

1. A minimum of one test per day per mix grade.
2. A minimum of one test per 100 CY for each grade of mix placed.
3. For deck overlays, one test at the frequency as specified in the QMP Ancillary Concrete special provision.

Compressive Strength

The contractor QC staff is responsible for casting, field curing, and breaking cylinders for each sample location. Depending on your contract, they may be a pair of opening cylinders, or they may be a pair of 28-day cylinders.

Air Content

The air content data shall be plotted on a copy of WS5013.

Temperature

The recording of concrete temperature during the fabrication of strength cylinders will provide the contractor information that may be useful on future projects. High concrete temperatures result in fast hydration of the concrete, thus reducing the time before sawing must occur. If the hydration process is too fast, it can result in shrinkage cracking and/or low strength. The temperature data shall be plotted on a copy of the WS5013.

Slump

A certified PCC technician I or IA should measure slump according to AASHTO T119. The contractor need not test slump for concrete placed by slip-form methods unless requested by the engineer. Provide material conforming to standard spec 501.3.7.1. Slump should be recorded on a copy of the WS5013.

Aggregate Gradation Sampling and Testing

Aggregate gradations shall be performed according to the QMP special provision and using AASHTO T11 and T27.

Department Testing

Verification and independent assurance sampling and testing will be performed by the department or a department representative as described in the provision. Sampling and testing will be performed by an HTCP certified technician.

Verification Testing

Verification testing will be performed by a department representative on samples collected independently of the contractor's samples in accordance with the provision. Testing of the material will be conducted in a separate laboratory and with separate equipment from the contractor's tests.

Independent Assurance Review

Independent assurance reviews will be conducted by a department representative in accordance with the provision and the department's Independent Assurance Program. These reviews will be made of the contractor's quality control and the department's verification sampling and testing equipment and personnel.

Dispute Resolution

Dispute resolution will be conducted according to the provision.

CONCRETE STRUCTURES

Quality Control Plan

The quality control plan shall be produced and submitted according to the provision.

Contractor Concrete Mix Design

The contractor is responsible for providing the design of the concrete mixture for use on the project and for any necessary adjustments during production. A mix design may be a new design or one used on a previous project. New mixtures are those that use different material sources or quantities than a previously used mix.

A PCC Technician II, hired or employed by the contractor, is required to develop and submit the mix design report to the engineer prior to the production of concrete for the project. The mix design must meet the conditions specified in the QMP provision. The report can include a number of different mix designs, but each mix design is required to have supporting laboratory or field test results. Multiple mix designs will enable the use of the most appropriate mix on a project for given conditions. The contractor must complete department worksheet WS5014 "Concrete Mix Design" and submit to the engineer. The engineer's signature verifies that the engineer had an opportunity to review the mix design.

A mix design may be transferred from one project to another if the quality control and verification test results verify consistent, satisfactory performance. To be used on a new project, a transferred mix should contain the same materials and proportions as that used on the previous project. A written and signed request for transfer of a mix design shall be submitted by the contractor. The written request must certify that the source and characteristics of the materials have not changed since the original mix design was issued. All supporting documentation shall be included with the request. This shall include a summary of the quality control and verification test results from the previous project(s).

With the initial use of a mixture in a production capacity, it is the contractor's responsibility to test the properties of the mixture in a trial batch prior to mass production. Trial mixtures must use the same materials proposed for the work. When necessary, minor adjustments may be made to a mix formula. The adjustments should be determined from the quality control test results. The adjusted mix formula must meet the conditions specified of the mix design in Subsection B.5 of the QMP provision.

A copy of the mix design shall be made available to all the interested project parties (i.e. engineer, contractor, QC Technician, QA Technician, Independent Assurance Technician).

Fly Ash or slag is required to be used as a partial replacement for Portland cement concrete. Class C fly ash shall be used at a replacement ratio of not less than 1.0 pounds (1.0 kg) fly ash per 1.0 pounds (1.0 kg) cement, in such quantity so that fly ash content is within the range of 15% to 25% of total cementitious material. Alternately, Grade 100 or 120 slag shall be used at a replacement ratio of not less than 1.0 pounds (1.0 kg) slag per 1.0 pounds (1.0 kg) of Portland cement, in such quantity so that the slag content is within the range of 20% to 30% of total cementitious material.

Concrete Plants

Plant start up shall include calibration of the plant and testing equipment. Prior to production, the plant and test equipment should be inspected by the contractor. The engineer may choose to waive his inspection based on the results of the contractor's report.

In addition, the concrete producer is required to record the quantity of the materials used in each batch. The contractor is required to measure, monitor, and record the addition of materials to the mix after discharge from the plant.

Aggregate Sampling & Testing

Aggregate gradation sampling and testing shall be performed according to the QMP provision.

Combined Gradation

A combined aggregate gradation analysis should only be conducted on samples collected during the production of concrete. This analysis is performed using the as-batched aggregate proportions for a production load of concrete. The batch proportions used for the analysis should be recorded from the plant at the time the aggregate samples are collected from the working faces of the stockpiles. After performing gradation testing for each aggregate sample, the combined aggregate gradation is calculated according to the form instructions. Record project data on department worksheet WS3012 "Combined Concrete Aggregate Gradation."

Specification Limits

Lower and upper (specification) limits for the combined gradation should be calculated as follows:

1. Determine the as-batched fractional portion of each aggregate gradation, by dividing the weight of the aggregate gradation by the weight of the total aggregate used in the batch.
2. For each gradation control sieve, multiply the upper and lower specification limits for each gradation by the fractional portion of that aggregate being used.
3. For each control sieve, add the resultant products, from step 2, for each aggregate's fractional upper specification limit and lower specification limit.

The specification part of the calculation sheet (lower part) will remain fixed unless a change is made in the aggregate proportioning. In which case, it will be necessary to re-calculate the specification limits.

Analysis of Combined Gradation Data

The data resulting from the combined gradation analysis is to be used by the QC personnel for evaluation of the mixture quality and for control chart plotting. Analysis should be conducted as follows.

First, complete WS3012 and determine the specification limits, by summarizing the principle gradations and performing the indicated calculations for the percent total retained and percent between sieves. Plot the combined gradation and limits on department worksheet WS3014 "Aggregate Gradation Chart".

The Aggregate Gradation Chart is used as a visual of where the combined gradation lies within the specification limits. If any blend changes are made the control chart running average values shall start over.

The provision requires the contractor to notify the engineer of adjustments made in the batching process. While movement within the specification envelope will be permitted to benefit the contractor's use of aggregate, any blend change resulting in a combined gradation outside the established envelope will constitute a significant adjustment to the mixture design. Such adjustments will require approval of the engineer and re-establishment of the specification limits, following the previously outlined procedures.

The gradation summary table and the aggregate gradation chart are intended to help the contractor make quality control decisions.

Aggregate Moisture And P200 Testing

Aggregate moisture and P200 tests are required during concrete production. Use department worksheet WS3010 "Worksheet for Calculating: Aggregate Moisture Content, Combined % Passing #200 Sieve, and Water/Cementitious Ratio" to calculate moisture content and combined P200. Record the P200 results on department worksheet WS3016 "P200 Control Chart". The quantities used must reflect a specific batch of concrete (not mix design quantities); therefore, as aggregate samples are collected the technician must also obtain current batch quantities.

Concrete Testing

Materials Reporting System

The contractor submits mix information and test results for concrete placed under the structures QMP using the department's Materials Reporting System (MRS) software. available on the department's web site at:

http://www.atwoodsystems.com/mrs/

Water Cementitious Ratio

Water cementitious ratio (W/Cm) is an indicator of concrete quality. High water contents result in lower strength. W/Cm below 0.42 is desirable.

The W/Cm is calculated according to Figure 1. Quantities used must reflect target batch weights for production concrete; therefore, when an individual aggregate moisture content changes significantly, the technician must also obtain current target batch quantities and adjust the target batch weights to maintain the design W/Cm. If using mobile transit mixer trucks, be sure that the technician includes the water added on-site to the mix drum.

$$\text{Water Cementitious Ratio} = \frac{\text{Weight of Net Water}}{\text{Weight of Total Cementitious Material}}$$

$$\text{W/Cm} = \frac{\text{MW} + \sum \text{AFM}}{\text{C} + \text{ASH} + \text{SLAG}}$$

Where:

$\sum$AFM = $AFM_1 + AFM_2 + AFM_3 + ... + AFM_n$
AFM = the weight of free moisture contributed by each aggregate
W/Cm = ratio of water to cementitious material
MW = the weight of mix water added to the batch
C = weight of cement
ASH = weight of fly ash
SLAG = weight of slag

For the weight of free moisture contributed by each aggregate, AFM:

$$\text{AFM} = W_{Batch}\frac{\text{TM} - \text{AC}}{1 + \text{TM}}$$

Where:

W_{Batch} = the batch weight of the aggregate at field moisture;
TM = percent of total moisture of the aggregate expressed as a decimal fraction based on oven dry weight;
AC = percent absorption of the aggregate expressed as a decimal fraction based on oven dry weight.

Figure 1: Calculation of the Water Cementitious Ratio

In order to make this information useful to the batch operator, timely results are necessary. Work should begin immediately after the samples are collected and results should be shared as soon as they are available.

Defining Lots & Sublots

The contractor must define all lots on the project before placing any QMP concrete. Predefining the lot sizes and locations prevents contractor manipulation that might bias the strength test results. The contractor may need to adjust the planned lot sizes and locations to match the actual construction operations. These adjustments are allowable if they do not introduce bias.

The contractor must define lots that do not exceed 500 cy (400m^3) of material from a single mix design. Each lot must be subdivided into sublots that do not exceed 50 cy (40m^3). If a lot contains less than 4 sublots, there is not enough information to establish a meaningful percent within limits (PWL) statistic, and therefore there is no opportunity for the contractor to earn a strength incentive for that lot.

The contractor should try to create lots that logically correspond to their construction operations. Encourage the contractor to define smaller lots if the work is spread out over time or if a number of smaller individual components are being constructed.

Within each lot, the contractor should try to designate sublots that are all about the same size. Each sublot, however, is weighted by its volume for pay determination.

Contractors will usually prefer to do the minimum required testing. Remind the contractor that under a statistical specification, it may be in their interest to define their lots and sublots rationally to reduce potential variability.

Examples:

1. A series of bridge footings is to be poured in a day. These footings contain 40 cy ($30m^3$) of material. For this pour, the contractor may want to create one sublot to represent the concrete that is placed on that day.
2. A 700 cy ($540m^3$) deck is planned. This pour requires at least two lots. The contractor may want to divide the pour into two lots of 350 cy ($270m^3$) each, and subdivide each lot into 7 sublots of 50 cy ($40m^3$) each.
3. A small project contains two 35 cy ($23m^3$) abutments and a 80 cy ($30m^3$) deck. Since the total quantity of concrete under the Concrete Masonry Bridges bid item for the project is 150 cubic yards, "QMP Lite" provisions apply. Here the contractor is instructed in A.3 of the special provision to divide the project into at least 3 approximately uniformly sized sublots.

   If the contractor wants the benefit of a full statistical analysis and a possible strength incentive, they must create 4 or more sublots. In this example it may make sense to define two 35 cy sublots for the abutment work and two 40 cy sublots for the deck.

Slump

Perform slump tests of concrete mixtures according to standard spec 501.2. Slump test results must be documented with appropriate sample identification information on a copy of the Air Content Control Chart Masonry for Bridges.

Temperature

High concrete temperatures result in fast hydration of the concrete, and can result in shrinkage cracking and/or low strengths. Temperature data must be recorded on a copy of the Air Content Control Chart Masonry for Bridges.

Air Content

The contractor plots air content data using the department's MRS software.

Compressive Strength

The contractor QC staff is responsible for fabrication, curing, and strength testing for standard-cured cylinders required under the QMP. These cylinders are independent of the field-cured opening strength cylinders that the contractor casts and breaks to determine when to remove forms, falsework, or open to service.

Fabricating & Curing Cylinders

The contractor QC staff fabricates, cures, and tests cylinders to determine the 28-day compressive strength for each sublot. A set of three 6X12 inch QC cylinders is required. An additional set of three companion cylinders is required for sublots the engineer designates.

The contractor selects 2 of the three QC cylinders at random and breaks them. If the breaking strengths are close to the same, the average strength of those 2 cylinders defines the sublot strength. If the 2 breaking strengths are significantly different, the contractor breaks the third QC cylinder and determines the sublot strength as the average of the 2 highest strength cylinders.

The contractor records cylinder fabrication data using the department's MRS software.

Care should be taken during casting, curing, transporting, and breaking cylinders to avoid anything that might bias the strength results. If vibrating cylinders, the technician should take particular care to avoid over-vibration that can cause segregation and lower strength. Although poor technique generally gives inconsistent and lower compressive strengths which will hurt the contractor, some irregularities may benefit the contractor.

All HTCP certified technicians are trained to follow the same standard procedures. The department's independent assurance staff are charged with monitoring all project testing, whether by the contractor, the department, or a consultant, to make sure that those standard procedures are followed.

Companion Cylinders

The engineer tells the contractor where to cast companion cylinders by designating a sublot. The contractor is initially responsible for those cylinders, but the engineer should take possession of them as soon as it is practical after the 24-hour initial curing but no later than 3 calendar days after they are cast. The engineer should initiate standard curing (in a temperature and humidity controlled curing room or tank) as soon as they take possession of the companion cylinders. The purpose of the companion cylinders is to check for excessive variability in strength of cylinders made from the same sample by the same person, cured under like conditions, but tested with different equipment. If standard procedures are not followed, the results have little or no value. If the department fails to designate a companion cylinder sublot, or subsequently mishandles cylinders, and the contractor has fulfilled their obligation under the contract, the contractor will not be held responsible for missing or questionable companion test results.

Strength Test Results

The 28-day strength is the benchmark strength the department uses for structure design, the primary measure of concrete quality, and to determine incentive/disincentive pay adjustment. The average strength of the two QMP cylinders from each sublot defines the 28-day compressive strength for that sublot.

Pay Adjustment for Strength

The department determines a pay adjustment for 28-day compressive strength. For lots with less than 4 sublots, each sublot is evaluated individually. For lots with 4 or more sublots a statistical analysis is done to determine a lot-by-lot pay adjustment.

After verifying the contractor's data, the department calculates pay adjustments using the department's MRS software. The contractor must submit the required strength test information electronically using the MRS software available on the department's web site at:

http://www.atwoodsystems.com/mrs/

The department administers incentives and disincentives under different items. The unit for both items is dollars. The engineer should always use these items for pay adjustment. On smaller jobs there may be a single pay adjustment done for the entire project. On larger projects pay adjustments may be issued with progress payments.

The incentive item, Incentive Strength Concrete Structures, Item 502.0400.S, is included in the contract schedule of items as a predetermined price fixed at bidding. The fixed cost for the item is estimated at 80% of the maximum available incentive for the project. This item allows the engineer to pay incentive without a construction change order. Because a contractor can earn 0% to 100% of the maximum strength incentive attainable for the project and the contract bid item was at 80% of the maximum attainable, a project can result in 0% to 125% pay for the incentive for compressive strength bid item.

The disincentive item, Disincentive Strength Concrete Structures, 804.6055, is an administrative item included in the Field Manager reference files to allow the engineer to assess a disincentive but requires the addition of the administrative item by contract modification.

Pay Adjustment for Small Lots (less than 4 sublots)

The contractor is free to establish lots with less than 4 sublots. With 4 sublots a statistical analysis is still meaningful, but with less than 4 sublots it is of questionable value. The department calculates the pay adjustment for a lot with less than 4 sublots by treating each sublot individually. Sublots with an average sublot strength greater than or equal to the specification limit receive no adjustment. Sublots with an average sublot strength less than the specification limit receive a disincentive.

Statistical Pay Adjustment (4 or more sublots)

The department calculates the pay adjustment for a lot with 4 or more sublots using a percent within limits analysis (PWL) based on lot statistics, the lot mean strength, and the lot sample standard deviation. Only those lots with a standard deviation below a specified threshold are eligible for incentive payment. The lower quality index, how many standard deviations the lot mean is above the specification limit, is calculated and used to determine the PWL for a given sample size. The resultant PWL is applied to a pay equation to determine the appropriate pay adjustment per cubic yard for the lot.

The basis for the analysis is the sublot average strength, the average of 2 QC cylinders for each sublot. Weighted lot statistics are developed from the set of sublot average strengths as follows:

LOT MEAN:

$$X = \frac{C_1 w_1 + C_2 w_2 + C_3 w_3 + \cdots + C_n w_n}{W}$$

Where: X = lot mean
C = sublot average strength for each sublot
w = sublot weighting factor (sublot vol in CY)
W = Sum of weighting factors (lot vol in CY)

LOT STANDARD DEVIATION:

$$S_n = \sqrt{\frac{(C_1 - X)^2 w_1 + (C_2 - X)^2 w_2 + \cdots (C_n - X)^2 w_n}{(n-1)W \div n}}$$

Where: Sn = lot standard deviation
C = sublot average strength for each sublot
X = lot mean
w = sublot weighting factor (sublot vol in CY)
W = Sum of weighting factors (lot vol in CY)
n = number of sublots in lot

LOWER QUALITY INDEX:

$$Q_L = \frac{X - L}{S_n}$$

Where: QL =lower quality index
X = lot mean
L = specification limit
Sn = lot standard deviation

Additional Payment Considerations

Special circumstances may require the engineer to modify the pay adjustment calculated using the MRS software. Material that is represented by out-of-spec, outside the control limits, test results for other properties is not eligible for incentive payment. The engineer must deduct the appropriate amount from the lot pay adjustment that the spreadsheet calculates. Testing frequencies for those other properties (aggregate gradation, P200, air content, slump, and concrete temperature) may not correspond to the strength sublots. The engineer should note what additional adjustments were made and how the quantity was determined using the MRS software "redlining tools".

Department Testing

Companion Cylinders

In addition to the verification and independent assurance testing described in the special provision, the department is responsible for curing and testing companion cylinders. The department will compare the average strength of a pair of companion cylinders to the contractor's QC test results from the same sublot. If those average strengths vary by more than about 10 percent, the source of that variability should be investigated.

The point of companion cylinders is to isolate the potential sources of variability to handling and testing procedures that take place after the initial field curing. First check that the department has provided continuous standard curing and has prepared and tested the companion cylinders according to the applicable AASHTO standards. If standard procedures are not adhered to, the comparison has little or no validity.

There are a number of potential sources of variability. Contact the region IA personnel to help determine what may have caused the difference between the companion and associated QC strengths. IA personnel should be able to isolate the problem and suggest an appropriate remedy.

Document all companion test results. Be sure to indicate which QC cylinders were used in the comparison and indicate the results of that comparison even if the difference is less than 10 percent. Include details regarding any investigation done, the conclusions of the investigator, and actions taken to remedy the problem. Include this documentation in the permanent project records. The best way to assure that the information is not lost is to include it electronically in an RFI 155 report entered into the materials tracking system.